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Synopsis

*Can a country with limited defence resources mix it with the big boys in the International IM arena ?*

Australia with its limited research, development and manufacturing base cannot compete on the international scene in the provision of large weapon systems that conform to recognised IM standards. We do however, buy such systems and any influence we can exert on the large manufacturers and international policy makers helps to ensure that our IM requirements are met. The development of IM policies, input into data bases such as NIMIC and significant contributions in the areas of modelling, hazard assessment, protocols, testing and safety assessments have all helped in meeting the requirement. Manufacturing capability has also been enhanced. By carefully selecting niche areas, countries such as Australia can have significant inputs to the IM scene and be able to influence the activities of the big boys.

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*Can a country with limited defence resources mix it with the big boys in the International IM arena ?*

## **Introduction**

The Australian Defence Force (ADF) is not large when compared to those of the major world powers. Total service personnel number around 56,000 comprising 14000 Navy, 25000 Army and 17000 Airforce. In 1994/95 the Defence budget was \$9,000M which equated to 2.1% of GDP and of this approximately \$2,000M was spent on major capital equipment. This money supported programs that have been running over a number of years covering ship and submarine constructions, aircraft purchases and upgrades and improvements to ground force capabilities. Munition procurement to support the weapon systems is an integral part of these programs.

This emphasis on modernisation has also been felt in the munition manufacturing process where commercial approaches have resulted in the closure of inefficient factories, the upgrading of explosive manufacturing plant and the construction of a new filling and assembly facility, all without cost to the Defence budget. Opportunity was also taken to invest in new plant capable of processing new explosive compositions.

Behind all these initiatives has been the support of the Defence Science and Technology Organisation (DSTO) which provides advice on the application of science and technology best suited to the Australia's defence and strategic needs. DSTO, like all of us, have been subject to the changes brought about by a changing strategic outlook and tight financial constraints. The resulting competition for reduced resources has led to more emphasis on 'smart electronics' and less on the non glamorous and alleged mature technology area of explosives. This appears to be a world wide trend.

All these pressures have seen Australia swing away from the indigenous development of weapon systems towards buying overseas weapons at the high end of the technology spectrum whilst maintaining capability at the lower end of the spectrum. However, our geographical location, varying climatic conditions and different strategic outlook, dictate that we be able to exert some influence on overseas manufacturers to develop weapons that meet our operational and safety requirements.

## **Aim**

This paper looks at how 'small' countries can influence the 'big' manufacturers of defence systems to supply weapons that meet individual requirements by being smart customers through the application of research in niche areas and by implementing policies that align with accepted world wide trends.

## **Background**

Australia's links to the UK and USA through both historical and alliance considerations have led to the purchase of their defence equipment and to the adoption of explosive safety philosophies based on Northern Hemisphere and NATO standards. In recent years, acquisition of defence equipment has broadened to encompass other major world suppliers and led to a mix of different specifications. Our defence position has also shifted and we now concentrate on a strategic area of interest that encompasses SE Asia.

The safety of our weapon systems has always been a priority and this was given extra thrust with the formation of the Australian Ordnance Council (AOC) in the mid 1970s. This organisation was based upon the UK Ordnance Board and is responsible for providing impartial advice on the safety and suitability for service (S<sup>3</sup>) of weapons containing explosives. It has its equivalents in various guises in other countries.

Part of its role is to interpret overseas standards and tests applicable to explosives and to determine what is appropriate for the ADF. It also maintains an interest in the latest research activities covering the various aspects of explosives.

### **A strategy to achieve recognition?**

Being geographically isolated from the mainstream of international explosives safety policy formation has certain advantages as you can develop concepts aligned to your national needs whilst taking cognisance of emerging international trends. Small is sometimes beautiful; it tends to concentrate the mind on what is achievable within limited resources and manufacturing capability, it generates practical solutions and allows conception to implementation times to be shortened.

It does, however, require you to be aware of international trends and hence an important element of any strategy to influence the design of weapon systems and their explosive safety is to participate in collaborative arrangements and to share in the exchange of technology and policies. Attending international conferences is one way of effectively achieving this objective. The resulting knowledge allows you to focus on important niche areas where you have the expertise but stand back from areas of competition where 'might' rules.

This approach has resulted in Australia joining NIMIC, adopting an early policy on the need to consider Insensitive Munitions (IM) when purchasing weapons, having significant inputs in the fields of modelling and design protocols, adopting new explosive manufacturing capability and exploring new concepts in S<sup>3</sup> assessment, testing and cost benefit analysis. Australia is now accepted as being a force in these areas of explosives safety and the strategy has demonstrated that we can certainly mix it with the big boys. It is in the field of IM that this has most clearly been demonstrated and the following examples illustrate the point.

### **IM Policy**

Australia watched the international moves, led mainly by the USN and to a limited extent the UK, towards developing munitions that were less sensitive to unintended stimuli and in 1988 launched its own study into the perceived benefits of what by then were referred to as IM. This study by DSTO recommended that we pursue a policy of considering IM when purchasing weapons and this was taken further by the AOC who published a suggested IM policy in early 1991. Behind these decisions was the knowledge that Australia was embarking on a large capital procurement program that involved new weapon systems and that we had to take advantage of the safety improvements accruing from the research being undertaken on new energetic materials.

This is where small had its advantages and rather than tackling the problem from an individual service perspective or a procurement directive, a joint defence approach was adopted which led to the publishing of an Australian Defence Policy on IM in 1993. It was one of the first National policies on IM and incorporated the need to introduce IM into service in a sensible, practical and cost-effective manner when munitions were being procured or replenished/refurbished. A progressive and long term implementation approach is envisaged which will lead to procurement from those manufacturers committed to producing munitions complying with what are now generally agreed IM standards. Hence, there is an incentive for manufacturers to build weapons to meet this policy. Being one of the first national policies promulgated, it is also pleasing to think that it might be used as a reference document for other countries to adopt when considering their own attitudes towards IM.

## **NIMIC membership**

The IM policy issues also focussed our attention on the formation of the NATO Insensitive Munitions Information Centre (NIMIC) which pooled information on IM and used that to provide an analysis service to solve problems confronting the researchers, developers and users of IM. There were obvious advantages to Australia joining such an organisation where we could share our own knowledge in the IM arena and avail ourselves of the services provided. It would also help overcome some of our geographical isolation. We had to overcome the NATO problem but with the support of the original member countries and the foresight of the NIMIC founders who took into account such an eventuality during its formation, we became 'associates' in 1993 and fully fledged members in 1994. We also had the advantage of being able to share a technical data base on research into IM which had been generated through our efforts mainly in international collaboration programs.

The advantages of membership have been realised as attendance at workshops, contacts made over the broad spectrum of individuals and organisations involved with NIMIC and the technical analysis service provided have proved to be of mutual benefit. A 6 month secondment of a Royal Australian Naval Officer to assist NIMIC has also helped cement our ties with the organisation and demonstrate our commitment to its cause.

NIMIC membership has seen us, one of the 'small' boys, accepted by the 'big boys' as a worthwhile contributor to the field of IM and helped achieve the previously mentioned objectives of collaboration, access to policy formulation and learning through the exchange of cutting edge technology.

## **Cost Benefit Analysis**

Our policy requires the implementation of IM in a cost effective manner which infers the availability of an agreed approach to cost benefit analysis. This is not the case and the problem still exists world-wide although some countries are working in isolation on solutions that best fit their needs. I suspect that this is an area that could benefit from some sort of collaboration. Australia does not have a record of accidents involving explosives to help bolster the case for IM and hence DSTO was given the task of developing a cost benefit analysis approach that would fit the requirements of small production and limited procurement.

A review of overseas studies found that most of the existing IM cost-benefit methodologies considered specific platforms or storage situations and assessed the effect of changing all munitions in the scenario to IM. This approach only addresses a particular phase of the munition life-cycle and fails to meet the Australian requirement for a methodology that addresses the entire life-cycle. Such a requirement had been recognised by NIMIC who, during their pilot phase, published a general methodology for IM cost-benefit analysis. This has been used as the basis for Australian studies and application to the MK82 GP bomb and 5"/54 naval ammunition systems.

Factors specific to the Australian situation need to be examined before adapting any cost-benefit methodology. These include defence force size and structure, considerations of climate, economy, geography and demography. The cost-benefits of IM conversion of a munition system will be very different for a relatively small country like Australia compared to large countries such as the USA and the UK. The expenditure of large amounts of money on developing an IM version for a high-value low-inventory weapon system is unlikely to be cost-effective for Australia but other options offer more hope. These options include:

- ◆ Development of an IM variant for Australian use and overseas sales thus introducing a “profit” factor into the equation,
- ◆ Purchase of an IM variant from another country where it is cost-effective to develop one thus reducing the cost of procurement by eliminating the R&D and munition qualification costs,
- ◆ Co-operation between nations to develop an IM variant for mutual use thus distributing the costs whilst maintaining mutual benefits. This is likely to most applicable to high usage, lower value items such as an artillery shell or general purpose bomb.

## **Modelling and Small-Scale Testing**

The high costs of full-scale testing along with the associated problems of coping with the environmental impact of certain test configurations will lead to the use of modelling as a cost effective means of assessing design alternatives during development. The capability to accurately model the response of munitions to the various IM threat stimuli assists in the design of IM and reduces the need for testing. To develop accurate predictive modelling capabilities, we need a good theoretical understanding of the mechanics of initiation by the various threats and realistic input parameters for the codes. Australia has made significant contributions at the international level to this understanding in the areas of shear and hot spot initiation mechanisms for projectile impact, jet initiation mechanisms, modelling shock initiation and the detonation of non-ideal explosives.

Similar inputs have been made in collaborative fora to the understanding and development of predictive methodologies for cook-off reaction violence and delayed detonation reactions. These are both areas in need of urgent research. The development of a damage model which can be incorporated into a suitable ignition and growth model offers exciting prospects of being able to predict delayed detonation reactions. Ultimately, the knowledge and technology gained in these collaborative efforts will be transferred to NIMIC and hence used by weapon designers. Once again our inputs are influencing the design of new weapons that may eventually be procured.

We must maintain our own capabilities to assess and predict munition response to unplanned stimuli to be smart buyers of IM. Australia has developed a number of inexpensive and simple small scale tests to assist in this area as they are cheaper and easier to conduct than their full-scale counterparts. They are reliable, reproducible and give valuable scientific insights on the affects of varying thermal and other environmental factors on the mechanisms involved with initiation. Collaboration has enabled a number of these type of tests to be compared and the best selected.

## **Design Protocols**

In 1987, TTCP Subgroup W established an action group to identify critical technology shortfalls and opportunities in the areas of hazards of energetic materials and their relation to munitions survivability. In a series of workshops, this group addressed this subject in five threat-defined areas. These were fragment and bullet impact, cook-off, shaped charge jet impact, response to electrostatic discharge and sympathetic detonation. There were significant and valuable DSTO contributions to most of these areas and the outcome of the group was a series of “hazard assessment protocols”. Custody of these protocols has subsequently been transferred to NIMIC and refinement is continuing. These contributions will contribute to future design activities world wide.

A hazard protocol is an ordered procedure, or flow chart, which directs a user through the consideration of a hazard area. It is intended to be a design tool used early in the design cycle to anticipate potential hazard problems, and as an aid to personnel in mitigating existing munition hazard problems. It identifies the situations most likely to be encountered by an ordnance item in a real environment and which must be considered in developing an insensitive munition, and the information which must be obtained to perform a hazard assessment. Use of such protocols allows limited resources to be focussed on critical areas, and reduces the need for expensive large scale testing during IM development programs.

## **Manufacturing**

With a country the size of Australia, there is only room for one munitions manufacturer. This, combined with our geographical location, has meant that the Australian Government has concentrated heavily on issues which can be categorised as strategic. A number of larger countries are not faced with this problem when they can spread their demands over competing companies. However, we in Australia have had to come to grips with the government decision and develop strategies for overseas purchases of items not made in house.

The world munitions manufacturing community has applauded the decision of the Australian Government to support restructuring of our ammunition industry with ADI, Australia's indigenous munitions manufacturer, building a new green field ammunition manufacturing facility at Benalla, Victoria. In the UK we are seeing the re-emergence of Royal Ordnance as a primary supplier to the MOD(UK). This appears to have happened for two reasons, one being the internal restructuring of that company has made them more competitive, the other is that off shore suppliers whilst often cheaper than the home base are frequently neither as reliable nor do they provide the quality.

Another interesting aspect is the advantage of being a small scale producer. Because ADI maintains a small scale design, manufacture and test capability, it is better suited to secure niche markets which demand small variation from the norm in terms of performance. This has proved so in the small arms powders for the reloading market where ADI is now the largest supplier of this product into the USA. Similar advantages may occur in the small volume IM area.

The knowledge that the future of the munitions industry is secure encourages further investment by the manufacturer. The partnership between the Department of Defence and ADI gives this security. If this type of relationship were followed in other countries, efficiencies would result as they have in our country where prices have dropped by approximately 20%.

A long term plan to restructure and provide security for our munitions industry has allowed us to be competitive in niche markets and where small scale production is advantageous. With minimal capital outlay, a small scale manufacturer can install or maintain a capability to meet low demand economically when the "big boys" need big quantities to recover their costs.

## **Safety and Suitability for Service Assessment and Testing of Munitions**

The S<sup>3</sup> of munitions procured 'off the shelf' from overseas manufacturers poses its own problems. With the input at the design and development stage limited to the modelling and design protocols mentioned above, the safety assessments of other competent safety authorities, comparison with like munitions or contractual access to trials data are the most cost effective means available of conducting an analysis against your requirements. It is essential to maintain close contact with equivalent safety authorities through regular visits, Memorandum of Understandings and Data Exchange Agreements.

A thorough understanding of the environmental and operational requirements for the munition in service is essential. It is only through this knowledge that the safety and suitability testing requirements can be specified and the requisite test data obtained as part of the procurement contract. This is an area that is quite often ignored but one that can be of great advantage. Specifying a test regime is dependent on the ability to conduct an analysis of the combined risks and hazards associated with the use of the munition, the environment and the threats confronting it throughout its service life and then being able to convert these into a realistic and cost effective test program. We have watched with interest the development of the NIMIC threat hazard analysis model 'THAMES' and its modification from an IM based concept into a more encompassing S<sup>3</sup> matrix format by the Ordnance Board of UK.

A similar and parallel process has taken place within the AOC where we have concentrated on developing assessment guidelines based on the non or partial availability of test data and the need to keep to a minimum the additional cost of items for testing. Design safety principles are assessed by a combination of desk top analysis and by inputting S<sup>3</sup> performance objectives into user evaluation trials programs. Overseas test standards and specifications are compared to the Australian operational environment and those that most closely represent our requirements are used as guides. Gaps in test results are then noted and the consequences analysed. In this way, the expense of special test programs may be reduced or even avoided altogether.

### **Associated subjects**

Safety critical software and range safety are both areas that have seen significant initiatives taken by the AOC and associated authorities. The results of these initiatives are being applied over a range of munition safety considerations and have been cited in national and international fora.

#### **Safety Critical Software**

AOC Pillar Proceeding 223.93, (a guidance document) provides the framework for the development and assessment of safety critical systems which are to be developed and is concerned with the safety of personnel. The key steps in the approach are the analysis of potential system hazards, identification of safety critical components of the system and the subsequent assignment of software integrity levels (SIL) to those safety critical components; the Pillar Proceeding then prescribes the appropriate validation and verification activities to each SIL. This approach is less complex and less intrusive than that advocated by the UK DEF STANs 00-55 and 00-56 but is more substantial than the MIL-STD-882 approach. The problems of dealing with systems that are already developed is not covered in the Proceeding and assessment relies on the successful tenderer providing the source code and development analyses including validation and verification and testing. This is not unlike the problems discussed earlier for assessing the S<sup>3</sup> of weapons bought off the shelf.



## Risk Based Range Safety Methodology

In 1984 the AOC identified the need to review existing range safety procedures used by the ADF. These procedures were not based on any mathematical or statistical analysis but on range experience. Consequently, there was a need to develop an approach to range safety that addressed conflicting operational, commercial and community pressures and was quantitative and scientifically based.

Australia, in conjunction with member nations of the International Range Safety Advisory Group (IRSAG), agreed to develop an internationally accepted risk-based range safety methodology (RBRSM). In undertaking this task, two expert working groups (EWGs) were formed, EWG (Theory) to address development of the methodology (led by Australia) and EWG (Data) to address the acquisition of ricochet data (led by the UK).

In leading EWG (Theory), Australia was best able to apply effort in the development of the basic scientific principles and statistical processes upon which the RBRSM is based. In contrast, the development, support and conduct of the ricochet trials is quite an expensive undertaking well outside of the resources available to Australia, hence the primary involvement of the UK and US in the data acquisition area. The approach taken by EWG (Theory) was largely based upon work carried out by the University of Newcastle, New South Wales, under contract to the AOC. The RBRSM thus developed was formally accepted by the IRSAG in May 1994. Subject to the availability of good quality data, RBRSM provides an approach to range safety that is based upon documented scientific principles of legal standing and enables informed judgements on activity risks to be made.

## Conclusions

Shrinking defence budgets are forcing 'small' countries into purchasing weapon systems from the large suppliers rather than maintaining non competitive in-country capabilities. This has forced a rethink on the methods used to ensure that the weapon design incorporates your operational environmental requirements and how to assess the safety and suitability for service of these munitions. Strategies need to be developed that take into account the lack of access to safety test data particularly at the design and development stages and how to account for differences in national standards. This strategy also needs to extend into the indigenous manufacturing capability to ensure that it remains efficient and capable of competing in the world market in niche areas.

Intelligent use of available resources is the answer where emphasis is given to contributing expertise in areas that have the greatest impact on the principles and policies governing the design and assessment of weapons. Collaboration programs, formal data exchange arrangements, membership of international fora and the regular exchange of information through visits and seminars are an effective way of meeting the aim.

Australia has applied this strategy and through its work in policy formation, membership in NIMIC and collaborative research activities in the areas of modelling and design protocols has achieved international recognition particularly in the field of IM. In parallel it has also developed internal processes to cope with the problems of assessing the S<sup>3</sup> of weapons procured from overseas.